

CLAIMS

Having thus described our invention, what we claim as new and desire to secure by Letters Patent is as follows:

- 1 1. A computer implemented encoding and correcting method comprising the
2 step of performing only exclusive OR operations on words for error correcting
3 codes with four or more check symbols which can correct as many errors as
4 there are check symbols.

- 1 2. A computer implemented method for encoding data and correcting erasure
2 errors comprising the steps of:
 - 3 converting a code over a finite field of characteristic two which can
4 correct up to e erasure errors into a code which can correct up to e erasure
5 errors in words;
 - 6 encoding data using the converted code;
 - 7 reading the encoded data and correcting up to e erasure errors in
8 words.

- 1 3. The computer implemented method for encoding data and correcting
2 erasure errors recited in claim 2, wherein the converted code is a (3, 3) code,
3 wherein even if all the information in any three of the words w_i is erased, the
4 data can be recovered.

- 1 4. A computer implemented encoding and correcting method comprising the
2 steps of:
 - 3 transforming encoding and decoding matrices of $GF(2^n)$, the Galois

4 Field of 2^n elements for n greater than one, and
5 encoding data and correcting erasure errors using only exclusive OR
6 operations on words.

1 5. The computer implemented encoding and correcting method recited in
2 claim 4, wherein a (3, 3) code of distance four is used.

1 6. A computer implemented method for encoding and correcting four or more
2 erasure errors in data whose locations are known, comprising the steps of:
3 converting a code over a finite field of characteristic two into a code
4 whose encoding and correcting algorithms involve only exclusive OR (XOR)
5 operations of words;

6 reading data from main volatile memory and encoding the data using
7 only XOR operations to generate a correcting code;

8 storing data and correcting code in an auxiliary array of non-volatile
9 storage devices;

10 reading the data from the auxiliary array of non-volatile storage
11 devices; and

12 reconstructing erasure errors in the data read from the auxiliary array
13 of non-volatile storage devices using only XOR operations to generate
14 reconstructed data.

1 7. The computer implemented method recited in claim 6, wherein the code
2 whose encoding and correcting algorithms involve only XOR operations of
3 words is a (3, 3) code of distance four.

1 8. The computer implemented method recited in claim 7, wherein the code
2 whose encoding and correcting algorithms involve only XOR operations of

3 words is based on a code of six symbols, x_0, x_1, x_2, x_3, x_4 , and x_5 , each of which
 4 is an element of GF(4), the Galois Field of four elements, and where x_0, x_1 and
 5 x_2 are information symbols and x_3, x_4 and x_5 are check symbols, the check
 6 symbols being defined by:

$$7 \quad \begin{bmatrix} x_3 \\ x_4 \\ x_5 \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} x_0 \\ x_1 \\ x_2 \end{bmatrix}, \text{ that is } \underline{X}_C = A \underline{X}_1,$$

8 where a is an element of GF(4) which satisfies the equation $1+a+a^2=0$.

1 9. The computer implemented method recited in claim 8, wherein by
 2 substitution $\underline{X}_C = A \underline{X}_1$ becomes $\underline{W}_C = r(A) \underline{W}_1$, where \underline{W}_C is a correction
 3 word and \underline{W}_1 is a data word to be reconstructed.

1 10. The computer implemented method recited in claim 9, wherein, given a
 2 linear code over GF(2^n), the Galois Field of 2^n elements, which can correct up
 3 to e erasure errors, to a code which can correct up to e erasures in words, and
 4 whose encoding and correcting can be performed by XORing words, the
 5 method comprises the steps of:

6 encoding the linear code in the form $\underline{X}_C = A \underline{X}_1$, and each of the
 7 corrections is also of the form $x_i = B_i \underline{X}_1$, where A and the B_i s are matrices over
 8 GF(2^n);

9 choosing a representation, r , of GF(2^n), which representation assigns
 10 an $n \times n$ matrix, $r(a)$, for every element a in GF(2^n), whose elements are in

11 GF(2), i.e., are “0” or “1”;
12 obtaining the decoder of converted code by substituting the matrix $r(a)$
13 for every element a of A , to obtain the matrix A , and substituting w_i for x_i in \underline{X}_i
14 and in \underline{X}_C , where $w_i = (w_{i,0}, w_{i,1}, \dots, w_{i,n-1})'$ to obtain \underline{W}_i and \underline{W}_C , the encoder of
15 the code being $\underline{W}_C = r(A)\underline{W}_i$; and
16 substituting $r(a)$ for every element a of B_i to obtain $r(B_i)$ and
17 substituting w_j for every element x_j of \underline{X} to obtain \underline{W} to recover x_i by using
18 $w_i = r(B_i)\underline{W}$.

1 11. A computer system for correcting four or more erasure errors whose
2 locations are known, comprising:
3 a main volatile memory and an auxiliary array of non-volatile storage
4 devices connected for transferring data therebetween;
5 an encoding means for converting a code over a finite field of
6 characteristic two into a code whose encoding and correcting algorithms
7 involve only exclusive OR (XOR) operations of words, data read from said
8 main volatile memory being encoded by said encoding means using only XOR
9 operations to generate a correcting code and stored with the correcting code in
10 said auxiliary array of non-volatile storage devices; and
11 data reconstructing means which, when data is read from the auxiliary
12 array of non-volatile storage devices, reconstructs erasure errors in the data
13 read from the auxiliary array of non-volatile storage devices using only XOR
14 operations to generate reconstructed data.
1 12. The computer system recited in claim 11, wherein the code whose
2 encoding and correcting algorithms involve only XOR operations of words is
3 a (3, 3) code of distance four.